

CLAIMS

What is claimed is:

1. A fuel processing system comprising:
a fuel supply;
a first reactor having an inlet receiving fuel from said fuel supply and an outlet discharging a first reformat containing hydrogen, said first reactor operable to reform said fuel to form said first reformat; and
a second reactor having an inlet receiving fuel from said fuel supply and an outlet discharging a second reformat containing hydrogen, said second reactor operable to reform said fuel to form said second reformat, and said second reactor being coupled in parallel with said first reactor with said first and second reformates combining to form a reformat flow.
2. The fuel processing system of claim 1, wherein said first reactor is a partial oxidation reactor and said second reactor is a steam reforming reactor.
3. The fuel processing system of claim 2, wherein said first reactor is an autothermal reforming reactor.
4. The fuel processing system of claim 1, wherein said first and second reactors operate at different pressures.

5. The fuel processing system of claim 1, wherein thermal energy is extracted from said first reformat and used as a heat input for said second reactor.

6. The fuel processing system of claim 1, wherein thermal energy is extracted from said first reformat and used to vaporize a feed stream supplied to said second reactor.

7. The fuel processing system of claim 1, wherein thermal energy is extracted from at least one of said first and second reformates to heat an oxidant supplied to said first reactor.

8. The fuel processing system of claim 1, further comprising a catalytic oxidizer reacting a portion of said reformat flow to heat a downstream reactor.

9. The fuel processing system of claim 1, wherein said first reactor has a first transient response time and said second reactor has a second transient response time that is greater than said first transient response time.

10. The method of claim 1, wherein said first reactor has a first response time and a first hydrogen reformat capacity and said second reactor has a second response time and a second hydrogen reformat capacity and said first and second response times and hydrogen reformat capacities provide adequate hydrogen to a fuel cell stack operation over all transients and ranges of said fuel cell stack operation

11. A fuel cell system comprising:

a fuel supply;

an oxidant supply;

a first reactor having an inlet receiving fuel from said fuel supply and an outlet discharging a first reformat containing hydrogen, said first reactor operable to reform said fuel to form said first reformat;

a second reactor having an inlet receiving fuel from said fuel supply and an outlet discharging a second reformat containing hydrogen, said second reactor operable to reform said fuel to form said second reformat, and said second reactor being coupled in parallel with said first reactor with said first and second reformates combining to form a reformat flow; and

a fuel cell stack receiving an oxidant flow from said oxidant supply and said reformat flow, said fuel cell stack producing electricity from said oxidant and reformat flows.

12. The fuel cell system of claim 11, wherein said first reactor is a partial oxidation reactor and said second reactor is a steam reforming reactor.

13. The fuel cell system of claim 12, wherein said first reactor is an autothermal reformer.

14. The fuel cell system of claim 12, wherein said first reactor is an autothermal reformer which can operate as a partial oxidation reactor or autothermal reformer.

15. The fuel cell system of claim 11, wherein said first and second reactors operate at different pressures.

16. The fuel cell system of claim 11, further comprising a catalytic oxidizer reacting a portion of said reformat flow to heat a downstream reactor.

17. The fuel cell system of claim 11, further comprising a preferential oxidation reactor reacting a portion of said reformat flow and generating heat.

18. The fuel cell system of claim 11, wherein thermal energy is extracted from said first reformat and used to heat a downstream reactor.

19. The fuel cell system of claim 11, wherein thermal energy is extracted from said first reformat and used to vaporize a feed stream supplied to said second reactor.

20. The fuel cell system of claim 11, wherein thermal energy is extracted from at least one of said first and second reformates to heat an oxidant supplied to said first reactor.

21. The fuel cell system of claim 11, wherein said first reactor has a first transient response time and said second reactor has a second transient response time that is greater than said first transient response time.

22. A fuel processor comprising:

a fuel supply;

an autothermal reactor having an inlet receiving fuel from said fuel supply and an outlet discharging a first reformat containing hydrogen, said autothermal reactor operable to reform said fuel to form said first reformat; and

a steam reforming reactor having an inlet receiving fuel from said fuel supply and an outlet discharging a second reformat containing hydrogen, said steam reforming reactor operable to reform said fuel to form said second reformat, and said steam reforming reactor being coupled in parallel with said autothermal reactor with said first and second reformates combining to form a reformat flow.

23. The fuel processing system of claim 22, wherein thermal energy is extracted from said first reformat and used to heat said steam reforming reactor.

24. The fuel processing system of claim 23, further comprising a combustor that reacts a combustor oxidant flow heated with said thermal energy extracted from said first reformat and a fuel flow to heat said steam reforming reactor.

25. The fuel processing system of claim 22, wherein said autothermal reactor operates at a lower pressure than said steam reforming reactor.

26. The fuel processing system of claim 22, wherein thermal energy is extracted from said first reformat and used to vaporize a feed stream supplied to said steam reforming reactor.

27. The fuel processing system of claim 22, wherein thermal energy is extracted from at least one of said first and second reformates and used to heat an oxidant supplied to said autothermal reactor.

28. The fuel processing system of claim 22, further comprising a catalytic oxidizer reacting a portion of said reformat flow to heat a downstream reactor.

29. The fuel processing system of claim 22, wherein said autothermal reactor has a first transient response time and said steam reforming reactor has a second transient response time that is greater than said first transient response time.

30. A method of operating a fuel processing system to produce a reformat flow containing hydrogen at a predetermined rate, the method comprising the steps of:

- (a) determining a target H₂ production rate;
- (b) producing a first reformat flow containing hydrogen at a first rate in a first reactor receiving fuel from a fuel supply;
- (c) producing a second reformat containing hydrogen at a second rate in a second reactor receiving fuel from said fuel supply, said second reactor operating in parallel with said first reactor;
- (d) combining said first and second reformat flows to form a reformat flow containing hydrogen; and
- (e) adjusting at least one of said first and second rates so that said reformat flow is produced at said target H₂ production rate.

31. The method of claim 30, wherein step (b) further comprises producing all of said first reformat flow in an autothermal reforming reaction in said first reactor.

32. The method of claim 30, wherein step (b) further comprises producing at least a portion of said first reformat flow in a partial oxidation reaction in said first reactor.

33. The method of claim 30, wherein step (b) further comprises producing at least a portion of said first reformat flow in a steam reforming reaction in said first reactor.

34. The method of claim 33, wherein step (e) further comprises adjusting at least one of said first and second rates so that a majority of said reformat flow is provided by said second reformat flow.

35. The method of claim 33, further comprising the step of removing CO from said reformat flow in a low temperature shift reactor.

36. The method of claim 30, wherein step (b) includes producing at least a portion of said first reformat flow in a partial oxidation reaction and step (e) includes adjusting at least one of said first and second rates so that all of said reformat flow is provided by said first reformat flow during a cold start-up of the fuel processing system

37. The method of claim 36, wherein said partial oxidation reaction occurs at an oxygen to carbon ratio of at least 1.0.

38. The method of claim 36, further including the steps of:

(f) removing H₂O from said reformat flow in an H₂O adsorber;

and

(g) removing CO from said reformat flow in a CO adsorber.

39. The method of claim 38, further comprising the steps of:

(h) releasing adsorbed H₂O from said H₂O adsorber into said reformat flow as said H₂O adsorbent is heated beyond an H₂O adsorbent retention temperature; and

(i) releasing adsorbed CO from said CO adsorber into said reformat flow as said CO adsorbent is heated beyond a CO adsorbent retention temperature.

40. The method of claim 30, wherein step (e) includes adjusting said first rate so that said first reformat provides a majority of an upward transient change in said target H₂ production rate during an upward transient operation of the fuel processing system.

41. The method of claim 40, wherein step (b) further comprises producing a change in said first rate by increasing a portion of said first reformat produced in a partial oxidation reaction.

42. The method of claim 30, wherein said step (e) further comprises adjusting said second rate so that said second reformat provides a majority of a downward transient change in said target H₂ production rate during a downward transient operation of the fuel processing system.

43. The method of claim 42, wherein step (e) further comprises restricting said second reformat and increasing pressure in said second reactor.

44. The method of claim 30, wherein step (b) includes producing said first reformat in a partial oxidation reaction in said first reactor and step (c) includes producing said second reformat in a steam reforming reaction in said second reactor.

45. The method of claim 44, wherein said first reactor is an autothermal reforming reactor and step (b) includes producing said first reformat in at least one of said partial oxidation reaction and a steam reforming reaction in said autothermal reforming reactor.

46. The method of claim 30, wherein step (b) is performed at a first pressure and step (c) is performed at a second pressure different from said first pressure.

47. The method of claim 30, further comprising the steps of:
- (f) extracting thermal energy from said first reformat; and
 - (g) using said extracted thermal energy to heat said second reactor.
48. The method of claim 30, further comprising the steps of:
- (f) extracting thermal energy from said first reformat; and
 - (g) using said extracted thermal energy to vaporize a feed stream to said second reactor.
49. The method of claim 30, further comprising the steps of:
- (f) extracting thermal energy from at least one of said first and second reformates; and
 - (g) heating an oxidant flow supplied to said first reactor with said extracted thermal energy.
50. The method of claim 30, further comprising the steps of:
- (f) reacting a portion of said reformat flow in a catalytic oxidizer to produce thermal energy; and
 - (g) heating a downstream reactor with said thermal energy produced by said catalytic oxidizer.

51. The method of claim 30, wherein said first reactor has a first transient response time and said second reactor has a second transient response time that is greater than said first transient response time.